Optimal train scheduling in presence of track circuits
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Abstract

Up to the present shunting work at depots has been performed manually by many employees such as daily shunting plan makers, signalers, train guides, and drivers. This work is cooperative work that requires each worker to be in close contact with the other workers. Additionally, shunting work partially includes heavy, dirty and dangerous work. To simplify this complicated process, based on the concept of giving the driver the ability perform shunting single-handedly, the "Computer Aided Total Shunting Sytem" is being developed. This system aims to bring about a fundamental improvement in shunting work in our depots. Although the "Computer Aided Total Shunting System" currently being constructed and tested at Nakahara depot on the Nambu line is not scheduled for completion until the end of fiscal year 1994, here we present a summary of the points and purposes of the research.

1 The Current State of Shunting Work

In order to satisfy rolling stock scheduling plans which are based on the train diagrams (daily and weekly schedules of all trains), periodic rolling stock maintenance (routine inspections, equipment inspections and maintenance), trainset rearrangement, washing and cleaning operations, etc... are carried out in depots. When making a shunting plan, not only must shunting plan makers follow the rolling stock schedule plan, but also it is not possible to carry out types of work on certain tracks in the yard. For example, washing the outside of rolling stock is limited to tracks that have washing equipment and are close to water supplies. Thus, in order to carry
out work within these limited facilities efficiently, shunting work is required. This shunting work is composed of two parts. The first involves creating the rolling stock shunting schedules in order to carry out work in the depot. The second part carries out the actual shunting of the trains in accordance with this shunting schedule. The way these duties are carried out using current methods is described below.

Making the Shunting Schedule
Because the rolling stock schedule and rolling stock's objectives are changed daily the shunting plan maker prepares a shunting plan everyday. He then transmits its contents to signalers, train guides, drivers etc... In order to decrease the number of shunting operations, a veteran plan maker who is extremely familiar with the peculiarities of his specific depot is required to prepare this plan.

Shunting Operations
Signalers and train guides carry out the work of route setting and signalling in obedience to the shunting schedule and advance conditions. The driver of the rolling stock then operates his train in accordance to these wayside signals and indications.

2 Problems with the Present System and the Aims of Development

Assessing the problems with the present system and the corresponding aims of development we have the following:

Problems
i) Shunting work partially includes 3D work (3D = dirty, difficult, and dangerous) and thus should be eliminated. It also requires extensive manual labor which will become scarce in the future due to Japan's rapidly aging population.

ii) Current shunting work requires an expert to make the shunting schedule.

Aims of Development
i) To create the daily shunting schedule automatically

ii) To allow the driver to start shunting work using a wireless radio

iii) To perform the required shunting route control automatically

iv) To have shunted cars always be controlled from the front of the trainset with the train moving forward (This point eliminates the situation where a driver must "push" a trainset with an engine from behind.)
3 Development Purposes and Requirements

The development purposes and requirements are shown in the next table.

Table 1 The development purposes and requirements

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<th>System</th>
<th>Purpose</th>
<th>Requirement</th>
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<td>Automatic Daily Shunting Plan Generation System</td>
<td>• To make the daily shunting plan automatically</td>
<td>• Creating the daily shunting schedule</td>
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<td>• To allow recreation of the shunting schedule</td>
<td>• Countermeasures in case of unplanned event</td>
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<td>Shunting Route Control System</td>
<td>• To enable automatic route control according to the daily shunting plan</td>
<td>• Accurate transmission and display of information</td>
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<td>TRIGGER Wireless Communication Unit</td>
<td>• To be able to issue shunting requests as well as view route information and permission at a remote location</td>
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<td>Portable Wireless Train Controller</td>
<td>• To allow a driver to control his train from places other than the driver's cab using wireless communication</td>
<td>• Safety measures for the Wireless Remote Train Control Device</td>
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<td>Notch Link Device</td>
<td>• To prevent a train from erroneously entering an unopened route</td>
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Creating the Daily Shunting Schedule

This function is outlined in Fig. 1. Because each train carries out different work it is necessary to make a new daily shunting plan at the depot everyday. In order to create this shunting plan by
computer, it is necessary to make decisions that satisfy the input requirements such as "On what track will the work be carried out?", "What routing should be used to get to this track?", etc... must also be considered. In making these decisions, the expert shunting plan maker's know how was codified into rules for an artificial intelligence algorithm.

Countermeasure in the Case of Unplanned Event
This function is outlined in Fig.2. After creating the shunting schedule, the shunting plan data is transmitted to the automatic route control system and used at the time of route control operations. In the event of an accident or delay, when the planning data become obsolete, route control is then performed manually by signalman. However, to prevent continuous manual operation, a function that allows recreation of the shunting schedule from a designated phase in time was built in to the system.

Accurate Transmission and Display of Information
This function is outlined in Fig.3. As for transmitting and displaying to the driver information about his own shunting requests as well as information about route openings, functions are built into the system to insure errors are not created in transmissions between the TRIGGER wireless communication unit used to carry out operations.

Safety Measures for the Portable Wireless Train Controller
This function is outlined in Fig.4. The Portable Wireless Train Controller abolishes "pushing" or "driving from the rear" operations that can occur when rearranging trainsets, and allows the driver to always control a trainset from the front where his view is not obstructed. In addition to monitoring the state of the train (pressure in the air reservoir and brake pipe), as well as safeguarding against radio interference such as electrical noise and cutout (Cyclic Redundancy Check etc ...), the Portable Wireless Train Controller has duplicate processors for the control data, feedback to check its control results, and self diagnostics to check itself for failure.

Safeguards Against Human Error
This function is outlined in Fig.5. Because shunting requests as well as the display of open routes are all carried out by radio, a large focus of the technical development involved linking the open route conditions to the train speed lever control "notch" as a safeguard against human error. At the time of a shunting request, this "notch link device" keeps the power to the trains driving circuit in the "off" state, unless an open route signal is present in
the same circuit to turn the power on.

4 Work Outline after Systematization.

The following is an outline of the new flow of work using the Computer Aided Total Shunting System. Work outline after systematization is outlined in Fig.6.

Making the Shunting Schedule

i) Data that is necessary to create the shunting schedule is input. These inputs include rolling stock schedules received from the maintenance office's systems, rolling stock inspection plans from the rolling stock maintenance department.

ii) Based on the data above the daily shunting schedule is generated and its contents are output to shunting route control system and train drivers.

Shunting Operations

i) Following the progress of the work situation and the contents of the shunting plan on the display, the driver issues requests to begin shunting using the TRIGGER wireless communication unit. Additionally, while protection devices prevent reception of signals other than the driver's requests, the train's driving circuits are turned to "off" by the notch link device.

ii) Upon receiving a driver's shunt request, the shunting route control system confirms the contents of the request with those of the shunting plan, and makes judgments about competition for a route and the presence of other vehicles along the course. Once again the notch link device blocks extraneous signals, and turns the train's driving circuit to "on".

iii) When these checks are completed, the train driver confirms their contents via the display of the TRIGGER wireless communication unit and begins shunting operations.

iv) As for vehicles entering and exiting the depot, according to the time table determined by the daily shunting plan the automatic shunting route controller automatically operates the required switchpoints.

5 Future Plans

Based on the above contents in this year we will complete construction of run tests on the "Computer Aided Total Shunting System". We aim to begin operation of this system at the Nakahara Depot by the end of fiscal year 1994.
Figure 1. Making the Shunting Schedule

Procedure to Prevent Conditions Manual Operation of Route Control after the Occurrence of an Unplanned Event

(Operation of Route Control) \(\rightarrow t\)

- Automatic Route Control
- Manual Operation
- Automatic Route Control

- Unplanned Events Occurs
- Recreated Plan is Implemented

Optimizing Processing Time in Creation of Shunting Plan

1. Man Machine Interface
   - Easy and Speedy System for Input of Changed Data
2. Recreated Plan
   - Online Recognition of Rolling Stock Positions gotten from Information from the Shunting Route Control System

Figure 2. Countermeasures in Case of Unplanned Events
Issuing Shunting Requests and Displaying Route Information using the TRIGGER wireless Communication Unit

1. Accurate Reception of Information from the Yard Interlocking Controller

Route Information
Positions of other vehicles

2. Rigorous Checking of Wireless Communications

Cycle Redundancy Checking between the Shunting Route Control System and TRIGGER wireless communication Unit

3. Methods of Display by TRIGGER wireless communication Unit

Last strict checking by Alternating Display of Informations

**Figure 3. Accurate Transmission and Display of Information**

- **Signal Transmission**
  - 1. Radio Cutout
  - 2. Electrical Interference

- **Rolling Stock**
  - 1. Loss of Pressure in Air Reservoir
  - 2. Loss of Braking Ability

- **Miscellaneous**
  - 1. Deadman Switch
  - 2. Self Diagostic Equipment
  - 3. Countermeasure in case of Theft

**Figure 4. Safety Features of the Portable Wireless Train Controller**

- **Emergency Brake**
  - Driving Circuit
  - Disable

- **Application of Variable ID.**
Route Permission and the Rolling Stock Notch Link Device

1. Insured Reception of Proper Signal
2. Downsizing
3. Cost Reduction

Figure 5. Safeguards Against Human Error

Making the Shunting Schedule

Shunting Plan Generation System

Shunting Plan Generation System

Shunting Route Control System

Maintenance Office's System

Watch Office's System

LAN

Shunting Operations

Shunting Request

Interface

Yard Interlocking Controller

TRIGGER Wireless Communication Unit

Portable Wireless Train Controller

Figure 6. Work Outline After Systematization